IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Optimization Of Electrical Discharge Machining Parameters For Aisi 304 Stainless Steel Using Response Surface Methodology

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ABSTRACT

EDM has become an important and cost-effective method of machining extremely tough and brittle electrically conductive materials. It is widely used in the process of making mould/dies, automobile and electronics industries where intricate complex shapes need to be machined in very hard materials. The work piece material selected in this experiment is AISI 304 Stainless steel taking into account its wide usage in industrial applications and it is very difficult to machine by conventional machining. The tool material selected in this experiment is copper based on the good electrical conductivity compared to other tool materials like brass, tellurium copper and graphite. In this work, the influence of variable process parameters such as pulse current, pulse on time, pulse off time, open circuit voltage, gap distance and machining time over performance characteristics like material removal rate, tool wear rate, and different aspects of surface integrity for AISI 304. Stainless steel such as topography of machined surface, crack formation will be investigated. The variations of material removal rate, tool wear rate versus input machining parameters will be optimized by using Response Surface Methodology which allows us to get best output characteristics.

Keywords: EDM, TWR, MRR, Stainless steel, Copper.

1 INTRODUCTION

Electrical Discharge Machining, commonly known as EDM is a non-conventional machining method used to remove material by a number of repetitive electrical discharges of small duration and high current density between the work piece and the tool. EDM is an important and cost-effective method of machining extremely tough and brittle electrically conductive materials. In EDM, since there is no direct contact between the work piece and the electrode, hence there are no mechanical forces existing between them. Any type of conductive material can be machined using EDM irrespective of the hardness or toughness of the material.

2 METHODOLOGY

B.S. Reddy et al. [1] carried out a study on the effect EDM parameters over MRR, TWR, SR and hardness. Mixed factorial design of experiments and multiple regression analysis techniques had been employed to achieve the desired results. The parameters in the decreasing order of importance for; MRR: servo, duty cycle, current and voltage; TWR: current, servo and duty cycle; SR: current; HRB: servo only. M.M. Rahman et al. [2] investigated the effect of the peak current and pulse duration on the performance characteristics of the EDM. The conclusions drawn were: the current and pulse on time greatly affected the MRR, TWR and SR, the MRR increases almost linearly with the increasing current, the SR increases linearly with current for different pulse on time, TWR increased with increasing peak current while decreased when the pulse on time was increased. I. Puertas et al. [3] carried out results which showed that the intensity and pulse time factor were the most important in case of SR while the duty cycle factor was not significant at all. The intensity factor was again influential in case of TWR. The important factors in case of MRR were the intensity followed by duty cycle and the pulse time. S.H. Tomadi et al. [4] investigated the machining of tungsten carbide with copper tungsten as electrode. The full factorial design of experiments was used for analyzing the parameters. In case of SR, the important factors were voltage and pulse off time while current and pulse on time were not significant. For MRR the most influential was pulse on time followed by voltage, current and pulse off time. Finally in case of TWR the important factor was pulse off time followed by peak current. Iqbal and Khan [5] concluded that the voltage and rotational speed of the electrode are the two significant parameters for EDM milling. Optimization is concerned with maximizing the MRR and minimizing EWR along with an optimum Ra. Norliana Mohd Abbas et al. [6] studied the research trends in dry wire EDM, EDM in water, EDM with powder additives, 13 EDM on ultrasonic vibration and modeling techniques in predicting EDM performances. For every method that was introduced and employed in EDM process, the objectives were the same: to improve the capability of machining performances, to get improved output product and to create better technologies to machine new materials.

Singh and Maheshwari [7] found that the input parameters such as current, pulse on time, voltage applied and the workpiece material greatly influences overcut. It increases with the increase of current but only up to a certain limit. It also depends on the gap voltage. Kiyak and Cakir [8] found that SR of workpiece and electrode were influenced by current and pulse on time, higher values of these parameters increased the surface roughness. Lower current and pulse time and higher pulse off time produced a better surface finish. B. Bhattacharyya et al. [9] observed that peak current and pulse on time significantly influenced different criteria of surface integrity such as surface crack density, surface roughness and white layer thickness. S Dhar et al. [10] came to the following conclusions: with increase in peak current MRR, TWR and ROC increased significantly in a nonlinear fashion; MRR and ROC increased with the increase in pulse on time and gap voltage was found to have some effect on the three responses.

3 EXPERIMENTAL SETUP

Figure 1 Dielectric reservoir

Figure 2 Control unit of EDM machine

Figure 3 EDM machinini Process

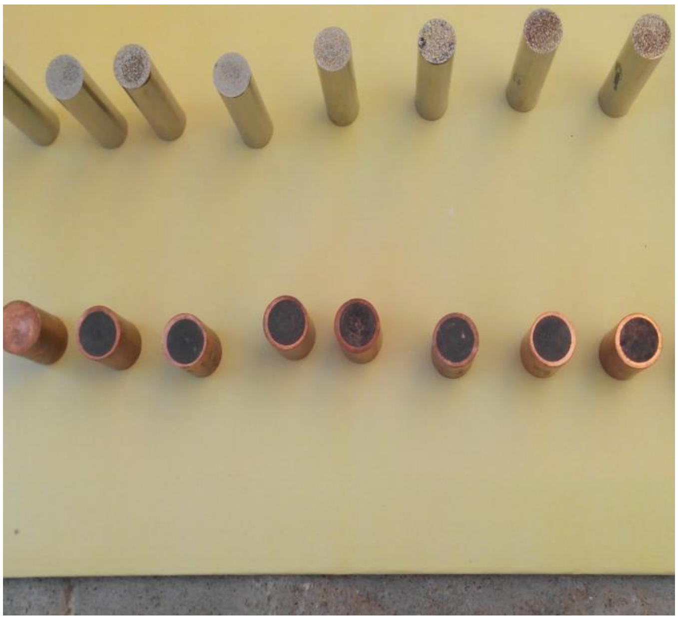


Figure 4 Model Workpieces

Response surface methodology (RSM) is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes. It also has important applications in the design, development, and Formulation of new products, as well as in the improvement of existing product designs. RSM is an important branch of experimental design in this regard. RSM is a critical technology in developing new processes, optimizing their performance, and improving the design and/or formulation of new products. It is often an important **concurrent engineering tool**, in that product design, process development, quality, manufacturing engineering, and operations personnel often work together in a team environment to apply RSM. The objectives of quality improvement, including reduction of variability and improved product and process performance, can often be accomplished directly using RSM. Use full for modeling and analyzing of problems in which output influenced by Several variables and the goal is to find the correlation between response and variables the true response function *f* is unknown, we must approximate it. In fact, successful use of RSM is critically dependent upon the experimenter's ability to develop a suitable approximation for *f*. usually, a **low-order polynomial** in some relatively small region of the independent variable space is appropriate. In many cases, either a **first-order** or a **second-order** model is Used. For the case of two independent variables, the first-order model in terms of the coded variables is

$$\eta = \beta_0 + \beta_1 x_1 + \beta_2 x_2$$

The three-dimensional response surface and the two-dimensional contour plot for a particular case of the first-order model, namely, $\eta = 50 + 8x_1 + 3x_2$

(**a**) Response surface for the first-order model (50 + 8*x*1 + 3*x*2) (**b**) Contour plot for the first-order model.

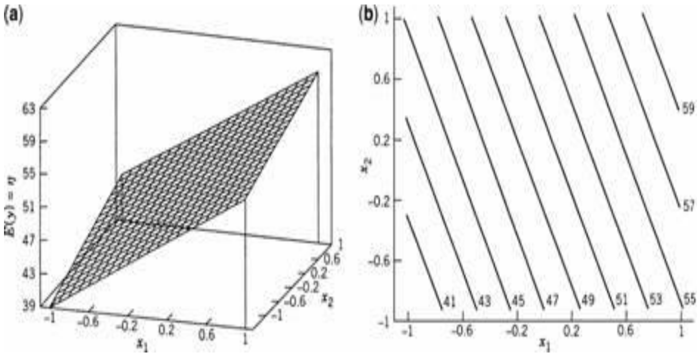


Figure 4 Three dimensional model 1

In three dimensions, the response surface is a plane lying above the *x*1, *x*2 space. The contour plot shows that the first-order model can be represented as parallel straight lines of constant response in the *x*1, *x*2 plane. Often the curvature in the true response surface is strong enough that the first-order model (even with the interaction term included) is inadequate. A **second-order model** will likely be required in these situations. For the case of two variables, the second-order model is

$$\eta = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2$$

presents the response surface and contour plot for the special case of the second-order model (**a**) Response surface for the second-order model **(b)** Contour plot for the second-order model.

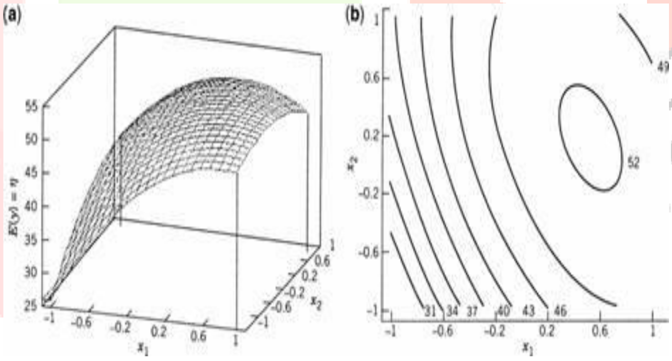


Figure 4 Three dimensional model 2

Notice the mound-shaped response surface and elliptical contours generated by this model. Such a response surface could arise in approximating a response such as yield, where we would expect to be operating near a maximum point on the surface.

The second-order model is widely used in response surface methodology for several reasons. Among these are the following

1. The second-order model is very **flexible**. It can take on a wide variety of functional forms, so it will often work well as an approximation to the true response surface. Several different response surfaces and contour plots that can be generated by a second-order model.

2. It is **easy** to **estimate the parameters** (the β’) in the second-order model.

3. There is considerable **practical experience** indicating that second-order models work well in solving real response surface problems

CENTRAL COMPOSITE DESIGN

It was introduced by Box and Wilson (1951). Much of the motivation of the CCD evolves from its use in **sequential experimentation**. It involves the use of **two-level factorial** or fraction (resolution V) combined with the following 2*k* **axial** or **star** points

F factorial points, 2k axial points, and nc center runs. The sequential nature of the design becomes very obvious. The factorial points represent a variance-optimal design for a first-order model or a first-order + two-factor interaction model. Center runs clearly provide information about the existence of curvature in the system. If curvature is found in the system, the addition of axial points allow for efficient estimation of the pure quadratic terms.

In effect, the three components of the design play important and somewhat different roles.

a. The resolution V fraction contributes substantially to the estimation of linear terms and two-factor interactions. It is variance-optimal for these terms. The factorial points are the only points that contribute to the estimation of the interaction terms

b. The axial points contribute in a large way to estimation of quadratic terms. Without the axial points, only the sum of the quadratic terms, can be estimated. The axial points do not contribute to the estimation of interaction terms.

c. The center runs provide an internal estimate of error (pure error) and contribute toward the estimation of quadratic terms

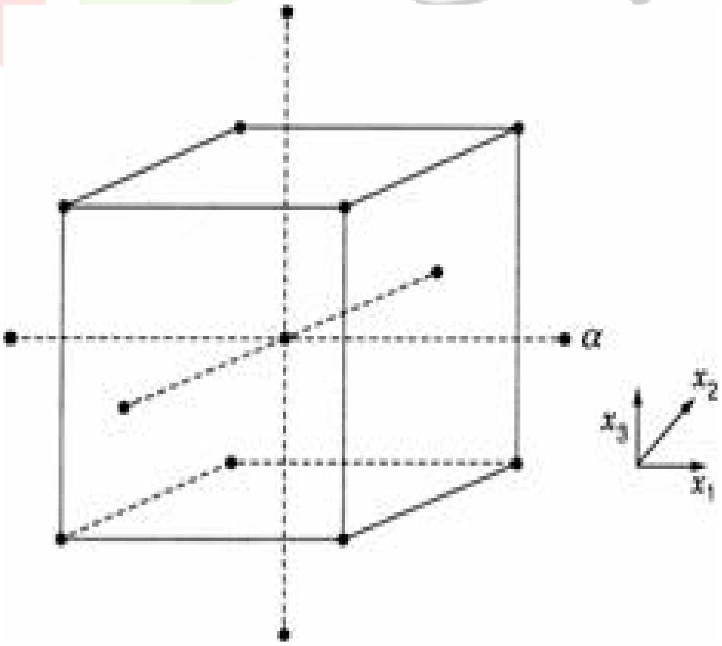


Figure 4 Three dimensional model 3

It can be shown that for the central composite design the rotatability requirement will be satisfied for

$$\alpha= 2n\,^{\wedge}4$$

This equation gives α=1.414 for n = 2, which is the same as the spherical design, however, for n = 3 we get α= 1.682 , which is slightly smaller than 3 With either a spherical design or a rotatable one, we find that we need a number of replicate center points (points at the origin) to obtain good prediction variance stability.

Figures show contours of prediction variance with one central point and five central points, respectively. It is obvious that the stability of the latter is much better than the former. ssThis need of central points with rotatable central composite designs is a possible problem with numerical experiments that give exactly the same answer when the experiment is repeated at the same point. Fortunately, however, with α=1 there is no need for repeated central points. The case of α = 1, which is called the face cantered, central composite design (FCCCD)

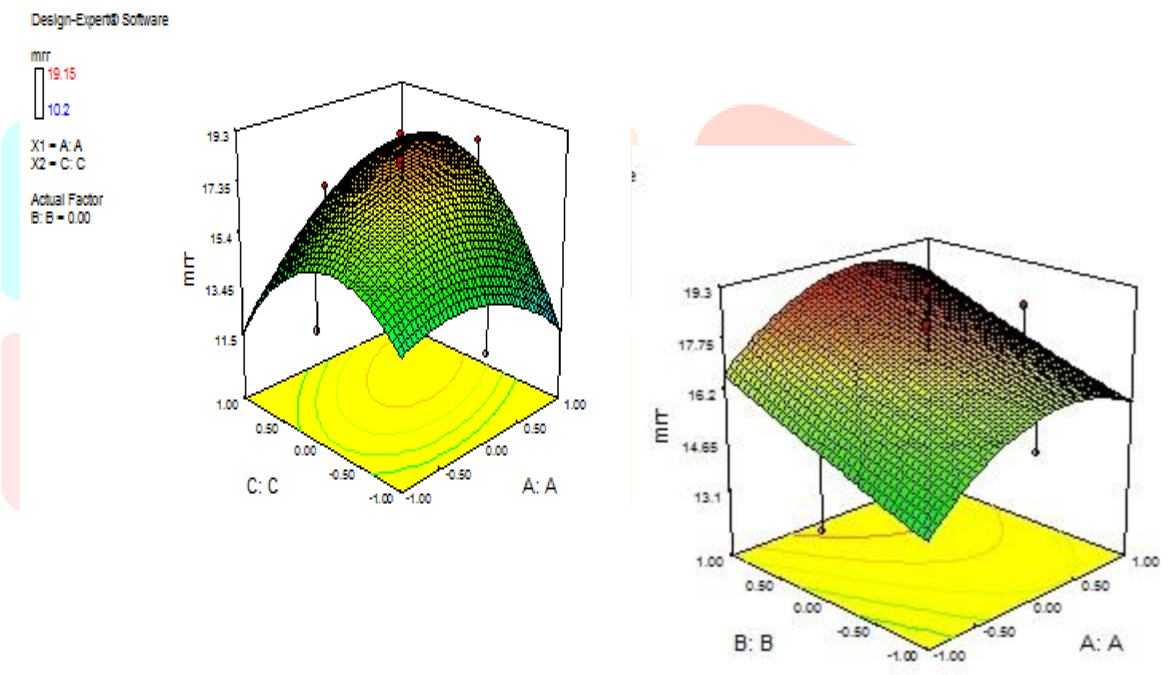
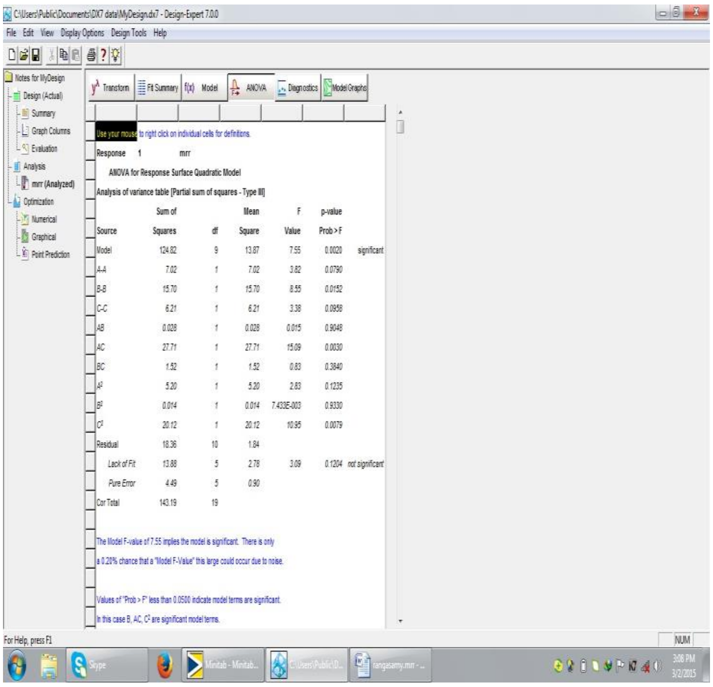


Figure 4 Three dimensional Analysed model



Use your mouse to right click on individual cells for definitions.

Response 1 mrr

ANOVA for Response Surface Quadratic Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	124.82	9	13.87	7.55	0.0020	significant
A-A	7.02	1	7.02	3.82	0.0790	
B-B	15.70	1	15.70	8.55	0.0152	
C-C	6.21	1	6.21	3.38	0.0958	
AB	0.028	1	0.028	0.015	0.9048	
AC	27.71	1	27.71	15.09	0.0030	
BC	1.52	1	1.52	0.83	0.3840	
A^2	5.20	1	5.20	2.83	0.1235	
B^2	0.014	1	0.014	7.433E-003	0.9330	
C^2	20.12	1	20.12	10.95	0.0079	
Residual	18.36	10	1.84			
Lack of Fit	13.88	5	2.78	3.09	0.1204	*not significant*
Pure Error	4.49	5	0.90			
Cor Total	143.19	19				

The Model F-value of 7.55 implies the model is significant. There is only
a 0.20% chance that a "Model F-Value" this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case B, AC, C^2 are significant model terms.

Fig 5.21 interaction graph between A and B.

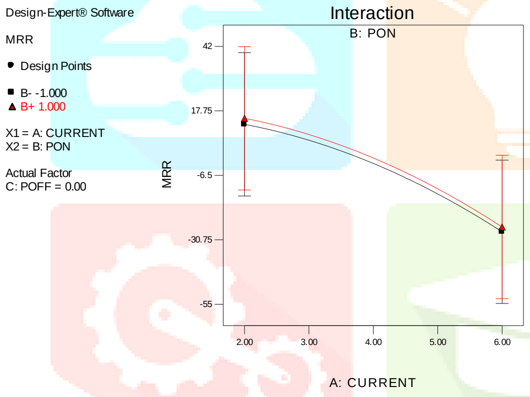


Fig 5.22 interaction graph between A and C.

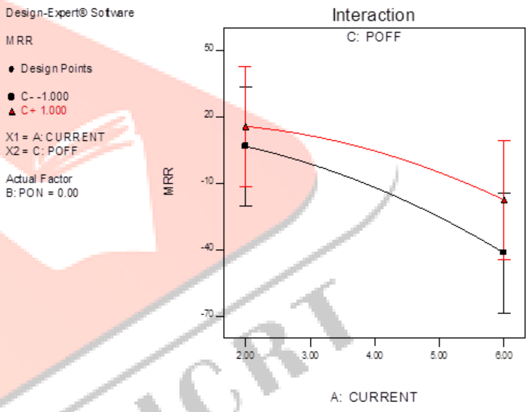


Fig 5.23 interaction graph between B and C.

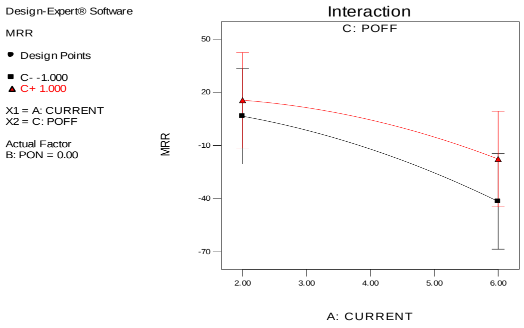
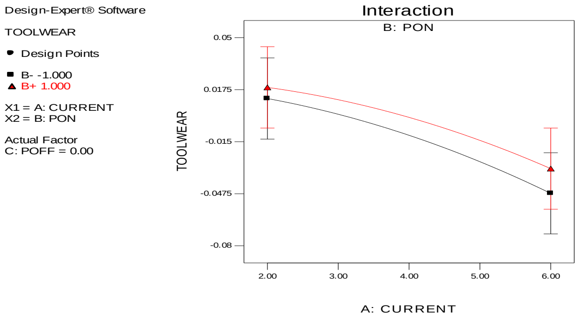


Fig 5.24 interaction graph between A and B.



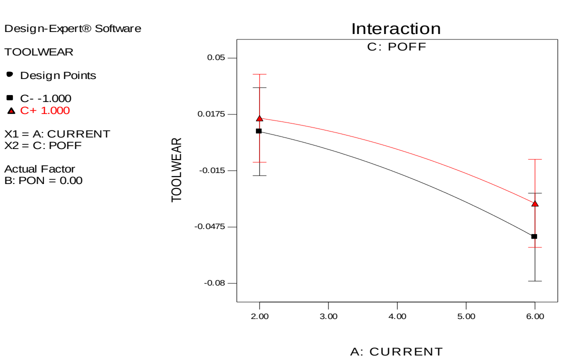


Fig 5.25 interaction graph between A and C.

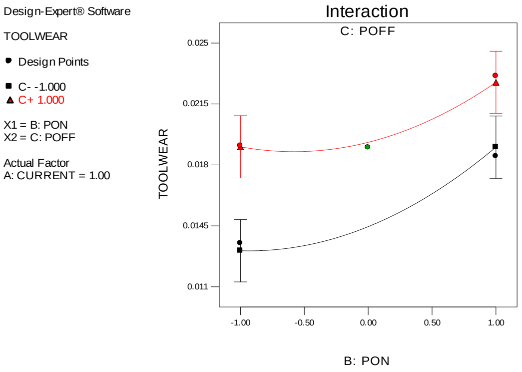


Fig 5.26 interaction graph between B and C.

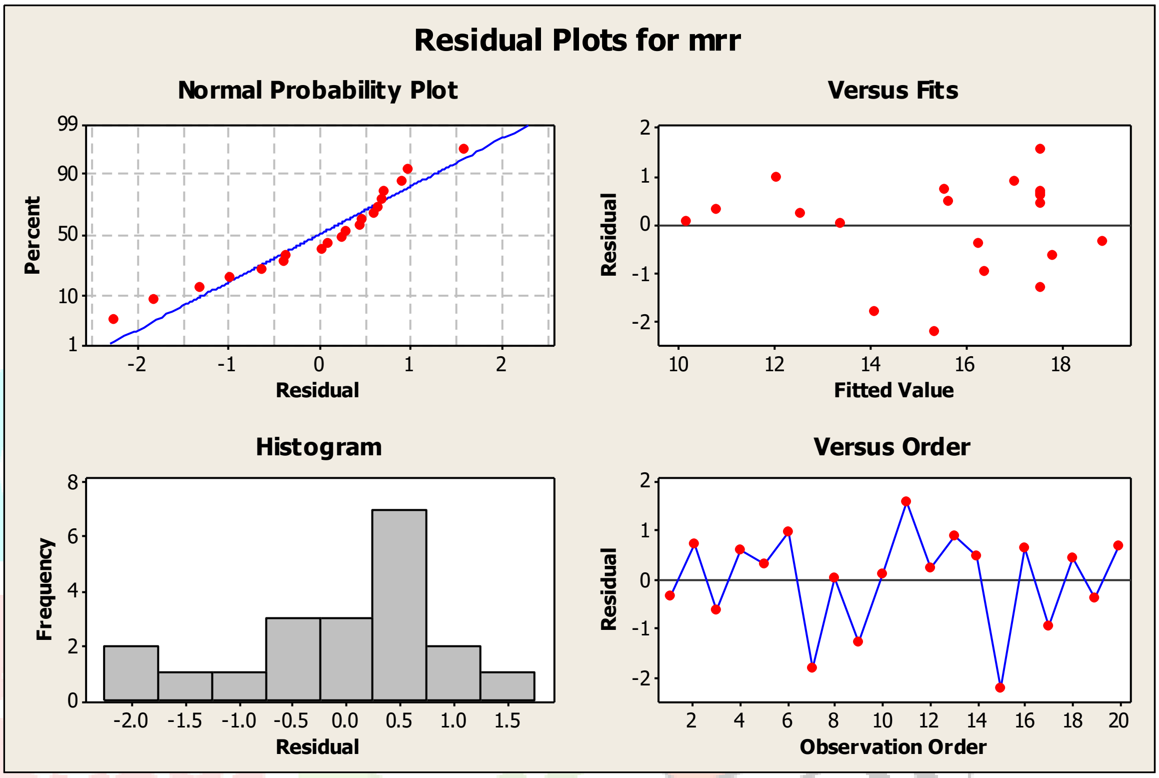


Figure 6 Residual plots for Material

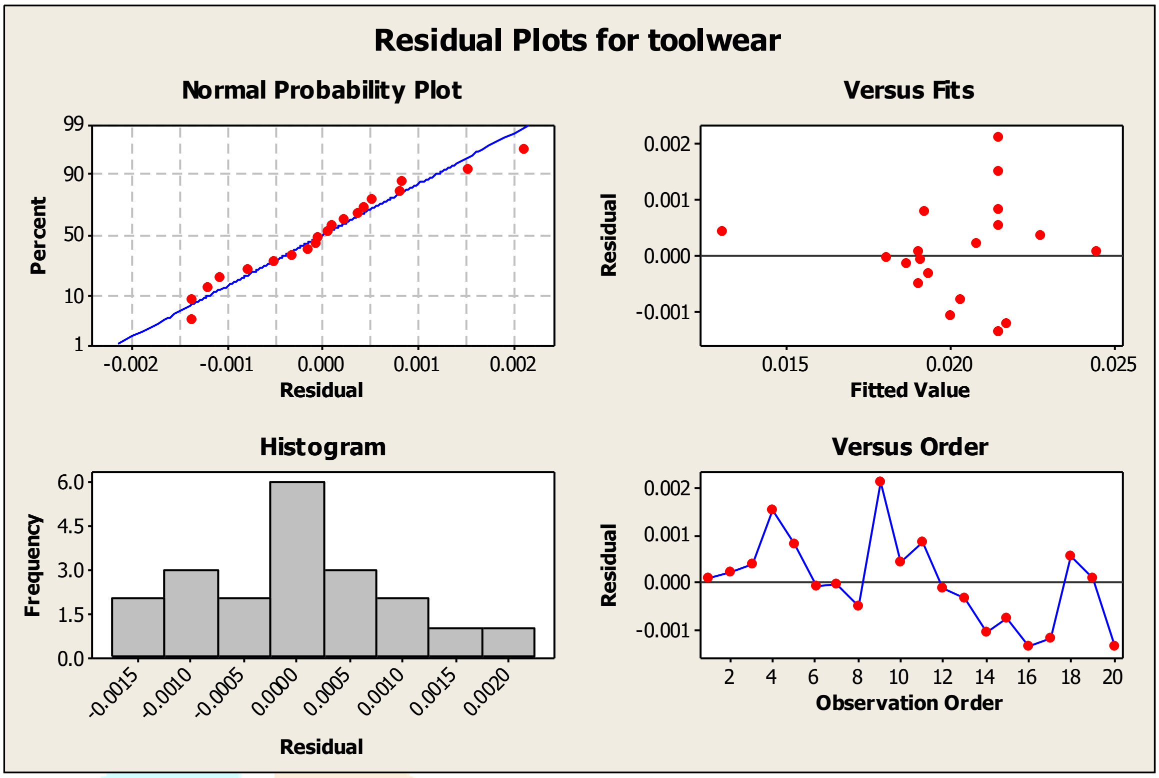


Figure 6 Residual plots for Toolwea

CONCLUSION

The work piece material selected in this experiment is AISI 304 Stainless steel taking into account its wide usage in industrial applications. This method has low cost compare to the conventional method and have higher material removal rate with lower tool wear rate.

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